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Method and Installation for Producing Dual-Phase Steel

The invention relates to a method and a device for producing dual-phase steel with a two-phase microstructure of 70 to 90 % ferrite and 30 to 10 % martensite from the hot-rolled state by a controlled temperature guiding and defined cooling strategy during the cooling of the steels, inter alia by means of water cooling after their finish rolling, wherein in a first cooling stage the cooling curve enters the ferrite region and, after reaching the required ferrite contents, further cooling to temperatures below the martensite starting temperature is carried out in a second cooling stage.

The targeted structural transformation by a corresponding cooling of the steels is known. For example, in DE 44 16 752 A1 a method for generating hot wide strip is described in which, before the first transformation, between the continuous casting device and a compensation furnace, the surface temperature of the slab is reduced to a sufficient depth (at least 2 mm) so that a structural transformation from austenite to ferrite/pearlite is achieved. In this context, the cooling time is selected such that at least 70 % austenite is transformed into ferrite/pearlite. A renewed transformation into austenite with new orientation of the austenite grain boundaries is carried out subsequently in the compensation furnace. In this way, it is to be achieved that even scrap metal of second quality, in particular, scrap metal with copper contents, can be used as a raw material without undesirable accumulations of copper on the grain boundaries of the primary austenite.

When manufacturing dual-phase steels, one ~~takes~~ also takes advantage of an occurring structural transformation by means of a targeted cooling, but now temporally after the transformation has occurred. The adjustment of a dual-phase microstructure depends in this connection significantly on the cooling speeds made possible by the device technology and on the steel composition. Important for the manufacture of dual-phase steels is a sufficient ferrite formation in the first cooling stage.

With respect to device technology, a sufficient ferrite formation is achieved, for example, by cooling with water to a temperature of approximately 620 - 650 °C with subsequent air cooling. The duration of air cooling (approximately 8 seconds) is selected such that at least 70 % of the austenite is transformed into ferrite before the second cooling stage begins. A transformation into the pearlite stage should be avoided during the first cooling stage as well as during air cooling.

In the second cooling stage there must still be so much cooling capacity present that hasp temperatures below the martensite starting temperature are achieved. Only then the formation of a dual-phase microstructure with ferrite and martensite components is ensured. This known manufacture presents no problem for small strip speeds because sufficient cooling capacities for the martensite transformation are available at the end of the first cooling stage.

For very high strip speeds, however, the beginning of the second cooling stage can be displaced within the current cooling stretch to such an extent that the subsequent martensite formation occurs

only incompletely or not at all because then the cooling capacity for adjustment of the required low-temperature (< 220° C) is no longer sufficient. A mixed microstructure of ferrite, bainite and proportions of martensite will result that cannot fulfill the desired mechanical properties of a pure dual-phase microstructure.

Based on this known prior art, it is an object of the invention to provide a method and a device for producing dual-phase steel wherein a fast and quantitatively sufficient structural transformation of the austenite into ferrite is possible even at high strip speeds.

The above object is solved according to the invention with the characterizing measures of claim 1 in that during the first cooling stage the cooling curve of the steels is adjusted with such a low cooling speed of 20 K/s to 30 K/s that the cooling curve enters the ferrite region with a temperature still so high that the ferrite formation can take place quickly and that already at least 70 % of the austenite has been transformed into ferrite before the beginning of the second cooling stage.

With the inventively slower cooling with a cooling speed lower than in known methods, the cooling curve enters the ferrite region temporally later but at a higher temperature than in the known methods, i.e., the transformation of the austenite into ferrite begins slightly delayed but at a higher temperature than in the known methods and it occurs also faster as a result of the higher temperature. It is especially beneficial when the ferrite region is reached as quickly as possible while at the same time the transformation temperature is high.

In comparison to the known methods, a degree of transformation of at least 70 % is reached so early that there is sufficient cooling capacity in a given cooling stretch for the subsequent martensite formation. This means that at the end of the first cooling stage a sufficiently large quantity of austenite has been transformed into ferrite so that the conventionally performed air cooling can be eliminated and the second cooling stage can follow immediately after the first cooling stage.

In order to perform the cooling with the desired low cooling speed, the principle of a dispersed cooling is applied according to the invention. This is a water cooling process in which water is applied to the goods to be cooled by water cooling stages arranged successively at a spacing. By adjusting the number of the water cooling stages, their spacing from one another, as well as the effective length of the water cooling stages, the cooling speed as well as the applied water quantity can be optimally adjusted to the goods to be cooled (the mass of the goods to be cooled and/or the surface of the goods to be cooled). The cooling can also be realized by a cooling medium quantity that can be adjusted continuously.

As a result of the adjustment to the goods to be cooled, the dispersed cooling can be temporarily expanded until the desired degree of transformation has been reached without there being the risk that, as in the known methods of fast cooling, the cooling curve leaves the ferrite region already beforehand as a result of cooling that is too intensive.

In comparison to cooling according to the prior art, by means of a dispersed cooling or cooling with a continuously adjustable cooling medium quantity, less water is applied until the transformation temperature is reached. This differential water quantity can now be applied during the transformation in order to force the carbon separation from the ferrite into the residual austenite and to thereby accelerate the ferrite formation. The residual austenite regions are enriched with carbon to such an extent that they transform into martensite already at cooling speeds of 20 - 30 K/s.

Since a defined holding period for the cooling in air is no longer needed in order to ensure a sufficient ferrite formation, the production of dual-phase steels can be realized on a portion of the cooling stretch. In this connection, the employed portion of the cooling stretch is very much shorter than in known methods with air cooling.

When the required microstructure components for dual-phase steels can be adjusted without air cooling, this results in significant advantages for the operator. Fewer device components are required for the production of dual-phase steels. At the same time, the production spectrum can be broadened in comparison to the prior art with changed process and strip parameters (for example, higher strip speed).

A device for performing the method of the invention is characterized by a cooling stretch arranged behind the last finishing roll stand and comprised of several water cooling stages positioned successively at a spacing or cooling systems with a continuously adjustable cooling medium quantity. The number of

water cooling stages, their effective length and their spacing from one another are changeable according to the invention so that this cooling stretch can be adapted in a simple way to changing geometries of the goods to be cooled as well as to different strip speeds.

Further advantages, details, and features of the invention result from the following description of an embodiment schematically illustrated in the drawings.

It is shown in:

Fig. 1 a schematic illustration of the fast cooling and the dispersed cooling as well as their arrangement in a mill train;

Fig. 2 a time-temperature-transformation curve;

Fig. 3 the degree of austenite transformation for fast transformation;

Fig. 4 the degree of austenite transformation for dispersed cooling.

In Fig. 1 the end of a mill train is schematically illustrated. It is comprised of the last finish roll stand (1), the rolling stock or goods to be cooled (2), and a hasp (3) with deflection rolls or drivers (4). Above this part of a mill train two different cooling stretches are shown. With the cooling stretch (5) according to the prior art an early, fast cooling of the goods to be cooled (2) is

realized by a continuous water supply. In the cooling stretch (6) according to the invention water cooling stages (7) are arranged successively at a spacing so that the cooling is "dispersed".

The different transformation results caused by the different cooling methods (5, 6) are represented in an exemplary fashion in the following schematic illustrations.

In Fig. 2, a time-temperature-transformation curve of the course of the cooling curve (9) for cooling according to known methods and the cooling curve (10) for a dispersed cooling are illustrated, wherein on the abscissa the time (Z) in seconds and on the ordinate the temperature (T) in °C are indicated.

The cooling curve (9) shows the cooling course for the strategy conventionally employed nowadays (early, fast cooling to a certain holding temperature with subsequent air cooling, followed by further cooling to lower temperatures below the martensite starting temperature). The first cooling stage (11) of the cooling curve reaches relatively early the transformation region for the ferrite formation (F = ferrite region) at the point (8) and also remains in this region (F) for a relatively long time as a result of the holding time (12) with air cooling before a further cooling to a temperature below the martensite starting temperature (M = martensite, B = bainite, P = pearlite) takes place by means of the second cooling stage (13) starting at the point (17).

In contrast, with the dispersed cooling the cooling curve (10) with its first cooling stage (14) reaches the ferrite region (F) at the point (15) later in comparison to the cooling curve (9). Since

after reaching the ferrite region (F) the dispersed cooling is initially maintained, no time-consuming waiting period with air cooling is required, and the cooling curve (10) leaves the ferrite region (F) earlier.

The dispersed cooling is maintained within the ferrite region (F) until the desired degree of transformation has been reached. The further cooling by means of the second cooling stage (16) is carried out directly thereafter.

The austenite transformation rates which can be achieved with the described different cooling strategies, i.e., the known fast cooling and the dispersed cooling can be seen in the two next illustrations of Figs. 3 and 4. The cooling time (Z) in seconds and the degree of transformation (U) of the austenite transformation into ferrite are illustrated on the abscissa and on the ordinate, respectively.

In the fast cooling (Fig. 3), during the first cooling stage (11) of the cooling curve (9) first a strong ferrite formation up to approximately 53 % takes place which then increases during the following air cooling (12) to approximately 62 %. However, this is not sufficient for the production of dual-phase steels.

In contrast thereto, with the dispersed cooling (Fig. 4) according to cooling curve (10) a considerably higher ferrite contents has already been formed in the first cooling stage (14) in the same time period and approximately 82 % austenite has already been transformed into ferrite before the second cooling stage (16)

occurs (the dual-phase steels produced nowadays have generally a contents of > 80 % ferrite).

The invention is not limited to the exemplary cooling curves described in the illustrations; other cooling curves as, for example, in cooling systems with a continuously changing cooling medium quantity are possible which, in keeping with the invention, result in higher transformation temperatures. Also, the invention is not limited to water cooling; other cooling systems can also be employed which lead to an earlier reaching of the ferrite region at high temperatures.